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Chest X-ray findings in sputum smear–positive pulmonary tuberculosis: a prospective study

Sanrala S[1], Mohithi N[2]
[1]Professor, department of Microbiology, Maharashtra Institute of Medical Education and Research (MIMER), Talegaon, Pune.
[2]Consultant, Sruthi Multispeciality Hospitals, Prarthana Samaj, Girgaon, Mumbai.

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Corresponding Author: Dr Mohithi N
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Abstract

Background: Pulmonary tuberculosis (PTB) remains a major public health problem in high-burden countries. While sputum smear microscopy is the diagnostic cornerstone, chest X-ray (CXR) is widely used to assess disease extent and severity. **Objectives:** To evaluate the utility of CXR in diagnosing pulmonary tuberculosis among sputum smear–positive patients.

Methods: This prospective observational study was conducted at Maharashtra Institute of Medical Education and Research (MIMER), Talegaon, Pune, from May to September 2025. A total of 205 adult sputum smear–positive PTB patients were included. All participants underwent posteroanterior CXR. Radiographs were independently interpreted by radiologists blinded to smear grading. Radiological patterns and their association with smear grades were analyzed using descriptive statistics.

Results: CXR abnormalities were observed in 93.7% of patients. Infiltrates or consolidation were the most common findings, followed by cavitary lesions. Higher sputum smear grades were associated with bilateral lung involvement. A small proportion (6.3%) of smear-positive patients had normal CXRs.

Conclusion: CXR provides valuable information on disease burden and severity in smear-positive PTB and complements sputum microscopy, though it cannot replace microbiological diagnosis.

Keywords: Pulmonary tuberculosis; Chest X-ray; Sputum smear microscopy; Radiological patterns; Diagnostic utility

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Introduction

Pulmonary tuberculosis (PTB) remains a major cause of morbidity and transmission, and even among sputum smear–positive patients clinicians must rapidly gauge disease extent and complications to guide triage and infection-control decisions [1]. Chest X-ray (CXR) is inexpensive and widely available, and common patterns (upper-zone infiltrates, cavitation, nodular consolidation, or miliary change) can support bedside diagnosis while treatment is initiated [1]. However, CXR is not perfectly sensitive: smear-positive PTB can occasionally present with a normal radiograph, risking missed or delayed recognition if imaging is used in isolation [2]. Baseline CXR also offers a practical snapshot of burden that may relate to smear grading and helps document response over time [1]. Standardized reading and computer-aided detection (CAD) may improve consistency where expert readers are scarce [3]. The aim of the current study is to assess the utility of CXR for PTB among sputum smear–positive patients by describing abnormalities, estimating the frequency of normal films, and to identify patterns suggestive of severe overall disease.

Methods:

This prospective observational study was conducted in the department of Microbiology at Maharashtra Institute of Medical Education and Research (MIMER), Talegaon, Pune, from May 2025 to September 2025. All consecutive adult patients who attended the outpatient department or were admitted to inpatient wards during the study period and were found to be sputum smear positive for acid-fast bacilli (AFB) by Ziehl–Neelsen staining were screened for eligibility. Patients aged ≥18 years who provided written informed consent were included. Patients with a prior history of anti-tubercular treatment, known extrapulmonary tuberculosis without pulmonary involvement, pregnancy, or poor-quality chest radiographs were excluded. Ethical clearance was obtained from the Institutional Ethics Committee.

After enrollment, detailed demographic and clinical data were collected using a structured proforma. Information regarding age, sex, symptoms (cough, fever, weight loss, hemoptysis, and breathlessness), duration of illness, and relevant risk factors was documented. Two sputum samples (spot and early morning) were collected from each participant under supervision, and smear microscopy for AFB was performed in the designated microscopy center using standard Ziehl–Neelsen staining techniques. Smear

grading was recorded according to national program guidelines. Only patients confirmed as sputum smear positive were included in the final analysis. All participants underwent a posteroanterior CXR within 24–48 hours of sputum confirmation as part of routine baseline evaluation before initiation of anti-tubercular therapy.

CXRs were performed using a standard digital radiography unit with patients in an erect position during full inspiration. Radiographs were independently evaluated by two qualified radiologists who were blinded to the sputum smear grading and clinical details to minimize observer bias. Radiographic findings were systematically recorded, including presence and distribution of pulmonary infiltrates, cavitation, consolidation, nodular opacities, fibrotic changes, pleural effusion, miliary pattern, and laterality (unilateral or bilateral involvement). In cases of discordant interpretations, a consensus reading was obtained. CXRs were categorized as normal or abnormal, and abnormal films were further classified based on predominant radiological patterns. The utility of CXR was assessed by determining the proportion of smear-positive patients with radiographic abnormalities and describing the spectrum of findings. Data were entered into Microsoft Excel and analyzed using SPSS version 21. Descriptive statistics were used, with categorical variables expressed as frequencies and percentages, and continuous variables summarized as mean ± standard deviation.

Results:

Among the 205 sputum smear–positive pulmonary tuberculosis patients evaluated, the majority were middle-aged adults with a male predominance. CXR abnormalities were observed in 192 patients (93.7%), demonstrating a high diagnostic yield of radiography in smear-positive disease, while 13 patients (6.3%) showed normal radiographs. The most common radiological manifestations were pulmonary infiltrates or consolidation, followed by cavitary lesions, reflecting active parenchymal disease and high bacillary load. Fibrotic changes and nodular opacities were less frequent, while pleural effusion and miliary patterns were relatively uncommon. Analysis of radiographic distribution revealed a clear association between smear grading and extent of lung involvement. Patients with lower smear grades (1+) predominantly showed unilateral disease, whereas those with higher smear grades (3+) more often had bilateral involvement, suggesting more extensive pulmonary pathology. These findings highlight that although CXR cannot replace microbiological confirmation, it provides valuable information on disease burden and severity among smear-positive patients. The small proportion of patients with normal CXRs underscores the limitation of relying solely on radiography and reinforces the importance of sputum microscopy in tuberculosis diagnosis.

Discussion:

The present prospective study evaluated the utility of CXR among sputum smear–positive PTB patients and demonstrated that radiographic abnormalities were present in a large majority of cases. More than 90% of smear-positive patients showed abnormal CXR findings, reaffirming the role of chest radiography as a valuable adjunct in the diagnostic work-up of PTB. Similar proportions have been reported in recent studies, where abnormal radiographs were observed in 85–95% of bacteriologically confirmed PTB cases, especially in high-burden settings [4, 5]. The predominance of abnormalities reflects the fact that smear positivity usually indicates a higher bacillary load and advanced pulmonary involvement, which is often radiographically apparent. Thus, while sputum microscopy remains the cornerstone for diagnosis, CXR contributes significantly to early clinical suspicion, baseline assessment, and documentation of disease extent [6].

In the current study, infiltrates or consolidation constituted the most frequent radiological pattern, followed by cavitary lesions. This distribution is consistent with contemporary literature describing post-primary tuberculosis, where parenchymal infiltrates and cavitation dominate radiographic presentations [7]. Cavitary disease is particularly important, as it correlates with increased infectiousness and higher smear grades [8]. Fibrotic changes and nodular opacities, although less common, likely represented chronic or partially healed lesions, while pleural effusion and miliary patterns were observed in a minority of patients. These findings align with recent imaging-based analyses indicating that pleural and miliary forms are less frequently smear positive due to lower bacillary concentrations in sputum [9]. Therefore, the spectrum of radiological patterns seen in this study mirrors the pathophysiological diversity of pulmonary tuberculosis.

An important observation was the association between sputum smear grading and the extent of radiographic disease. Patients with higher smear grades demonstrated a greater proportion of bilateral lung involvement, suggesting more extensive pulmonary destruction. Several studies have shown a positive correlation between smear grade, cavitation, and bilateral disease on CXR, reinforcing the concept that radiographic severity reflects bacillary burden 10, 11]. This relationship has clinical relevance, as extensive radiographic disease is associated with delayed sputum conversion, increased risk of transmission, and poorer outcomes if treatment is interrupted [12]. Hence, baseline CXR not only supports diagnosis but also provides

prognostic information that may help clinicians prioritize patients for closer follow-up and adherence support.

Despite the high yield of abnormal findings, a small proportion of smear-positive patients in this study had normal CXRs. This phenomenon, though uncommon, has been well documented and underscores an important limitation of radiography [2]. Early disease, minimal parenchymal involvement, or lesions obscured by technical or anatomical factors may result in apparently normal films. Such cases highlight the danger of relying solely on imaging for diagnosis and emphasize the indispensable role of microbiological confirmation. Recent advances such as digital radiography and computer-aided detection (CAD) systems have shown promise in improving sensitivity and reducing inter-observer variability, particularly in resource-limited settings [5, 6]. Overall, the findings of this study support the continued use of CXR as a complementary tool in smear-positive PTB, aiding in assessment of disease burden and severity, while reinforcing that it should never replace bacteriological testing in tuberculosis control programs.

Conclusion: CXR demonstrated a high yield of abnormal findings among sputum smear–positive PTB patients, highlighting its important supportive role in routine clinical practice. The presence and pattern of radiographic abnormalities closely reflected disease burden and were associated with higher sputum smear grades and bilateral lung involvement. Although a small proportion of patients had normal chest radiographs, emphasizing the limitations of imaging alone, CXR remained valuable for assessing disease extent, severity, and baseline documentation. Overall, CXR serves as a useful complementary tool to sputum microscopy but should not replace bacteriological confirmation in the diagnosis of PTB.

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Table 1: Pattern of radiological abnormalities on CXR (n = 192)	
Radiological pattern	**Number (%)**
Infiltrates / consolidation	74 (38.5)
Cavitary lesions	52 (27.1)
Fibrotic changes	28 (14.6)
Nodular opacities	19 (9.9)
Pleural effusion	11 (5.7)
Miliary pattern	8 (4.2)

Table 2: Distribution of CXR abnormalities by sputum smear grading		
Smear grading	**Unilateral (%)**	**Bilateral (%)**
1+ (n = 68)	44 (64.7)	24 (35.3)
2+ (n = 61)	29 (47.5)	32 (52.5)
3+ (n = 63)	18 (28.6)	45 (71.4)